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BY
B. A. WATSON, A.M., M.D.,
SURGEON TO THE JERSEY CITY CHARITY, ST. FRANCIS'S, AND CHRIST'S,
HOSPITALS, JERSEY CITY, N. J.

Extracted from the
Transactions of the American Surgical Association,
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AN EXPERIMENTAL STUDY OF ANÆSTHETICS.[1]

THE aim of this paper is to show, by experiments on rabbits and dogs, the physiological action and relative safety of those anæsthetics which are most frequently employed by surgeons. It is the author's desire to present clearly the results obtained in a series of experiments with chloroform, ether, bromide of ethyl, and various mixtures of these drugs, rather than theoretical arguments or philosophical deductions. We have, therefore, carefully noted the effects produced by these anæsthetic agents on the temperature, pulse, and respiration, together with the mortality, etc.; and shall present the same in a tabulated form, which enables us to deal with general results, instead of individual conditions. The object sought to be accomplished by this procedure is, the condensation of numerous observations made in individual cases after such had been carefully studied. It is considered highly important for the accomplishment of our object, that we mention briefly the various experimental procedures, in order that the work may be fairly understood. There were employed in our experiments eighty-two rabbits and twenty-five dogs. It is believed that all rabbits employed were full grown and healthy. The same may be said of the dogs, while their weight varied from six to fifty-six pounds, with an average of about twenty-five. The experiments on the rabbits were made by the aid of an air-tight cage, in which these animals were placed immediately after the normal temperature had been taken. All temperatures were taken with certified clinical thermometers, and the figures given in the following tables have been corrected by these certificates; furthermore, the instruments were introduced into the rectum the same distance, and at all times retained there at least five minutes. In all experiments on rabbits, the anæsthetic was placed in a Florence flask, which was connected with the experimental cage by means of glass and rubber tubing.

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[1] I desire to acknowledge the valuable services of Drs. J. F. Golding and Peter Hoffman, of Jersey City, N. J., in the performance of these experiments.

The anæsthetic was vaporized and forced into the experimental cage by the application of heat to the flask. As soon as complete anæsthesia had been produced, the rabbits were promptly removed from the cage and placed in the open air, where they were allowed to remain until the effect of the anæsthetic had partially passed off, when they were again returned to it. *The evanescent character of the anæsthesia produced by the bromide of ethyl rendered it impracticable for us to keep the rabbits continnously under its influence while we were engaged in taking their temperatures;* it is, therefore, evident that our figures in this instance show more favorable results than can be reasonably expected when complete anæsthesia is continuously maintained. Complete anæsthesia was maintained two hours in all of the other experiments; the first anæsthetic temperature was taken as soon after the production of this condition as was found practicable; and the same operation was repeated every half hour while the animal remained in this state. In taking the temperatures of the rabbits, there were never employed less than two, or more than four physicians in any experiment; it must, therefore, be apparent, that the time at which these temperatures were taken has been approximated, rather than stated exactly, since we commonly operated on twelve animals, and the taking of this number of temperatures by two persons would occupy something more than one half hour, while four would perform the labor in a little more than fifteen minutes. The observations in our experiments on the rabbits were practically limited to the temperature changes; but our study of the effects of the anæsthetics on the dogs included the variations in temperature, pulsations, respirations, and post-mortem appearances. In all our experiments on dogs the anæsthetic was poured on a sponge, which was placed within a leather cone and kept applied over the mouth and nose in such a manner as to keep up continually complete anæsthesia. Each physician was provided with assistance, and, therefore, enabled to devote his entire attention to the required observations; and consequently the records of these experiments are essentially accurate. The only interference which we experienced in making these observations arose from the occasional cessation of breathing of the animals, when the physician always promptly discontinued other labors and resorted to artificial respiration. It should here be observed, that in all our experiments on dogs, artificial respiration was promptly and thoroughly employed with the most satisfactory results; but in the experiments on rabbits no effort of this sort was made. It is now thought that we have so far described our experimental labors, as to render the tables intelligible, and, therefore, they may here be advantageously presented.

TABLE I.—FIRST EXPERIMENT WITH BROMIDE OF ETHYL.

Rabbit. No.	Normal temp.	Temperature during anæsthesia.			Temp. 24 hours after.	Temp. 48 hours after.
		Temp. at 3.10 P. M.	Temp. at 3.50 P. M.	Temp. at 5.10 P. M.		
1	102.1	100.00	dead	......	....	....
2	100.2	dead	......	......	....	....
3	102.3[a]	101.3	100.00	100.4	104.3	102.9
4	101.1	99.8	dead	......	....	....
5	102.0	102.4[b]	dead	......	....	....
6	101.4	103.0[c]	97.1	96.00	101.3	102.8
7	101.1	dead	......	......	....	....
8	102.1	100.3[d]	97.3	99.1	102.3	103.5
9	102.3[a]	dead	......	......	....	....
10	101.3	dead	......	......	....	....
Total,	1015.9	606.8	294.4	295.5	307.9	309.2
Average,	101.59	101.133	98.13[e]	98.5	102.63	103.063

Complete anæsthesia produced in 13 minutes. Mortality 70 per cent.

[a] Highest normal temperature.

[b] Temperature elevated.

[c] Highest temperature.

[d] Vomited.

[e] Lowest average temperature.

TABLE II.—SECOND EXPERIMENT WITH BROMIDE OF ETHYL.

Rabbit. No.	Normal temp.	Temp. during anæsthesia.		Temp. 24 hours after.	Temp. 48 hours after.
		Temp. at 3.15 P. M.	Temp. at 5.15 P. M.		
1	105.2	100.0[b]	dead	……	……
2	103.1	……[c]	101.8	102.8	103.0
3	103.1	103.5[d]	95.5[e]	103.7	103.3
4	103.5	103.8[d]	dead	……	……
5	103.9	103.1	102.3	102.1	103.0
6	104.8[a]	100.5	99.6	102.5	101.9
7	104.0	102.4	102.0	101.7	103.0
8	103.1	100.1	99.0	103.2	102.6
9	103.0	dead	…	……	……
10	104.3	101.7	100.2	103.0	103.6
11	103.4	dead	……	……	……
12	103.3	102.0	102.6	102.5	102.0
Total,	1244.7	917.1	803.0	821.5	822.4
Average,	103.725	101.9	100.375[f]	102.6875	102.8

Complete anæsthesia produced in 15 minutes. Mortality $33\frac{1}{3}$ per cent.

[a] Highest normal temperature.

[b] Thermometer broken *in situ*, and considerable hemorrhage ensued; rabbit died shortly after.

[c] Temperature not taken.

[d] Temperature elevated.

[e] Lowest temperature.

[f] Lowest average temperature.

TABLE III.—FIRST EXPERIMENT WITH CHLOROFORM.

Rabbit. No.	Normal temp.	Temperature during anæsthesia.				Temp 24 h'rs after.	Temp. 72 h'rs after.
		Temp. at 4 P. M.	Temp. at 4.45 P. M.	Temp. at 5.02 P. M.	Temp. at 5.41 P. M.		
1	103.1	103.1	dead	……	……	……	……
2	101.5	101.5	dead	……	……	……	……
3	101.8	102.1	99.5	99.7	98.7	100.7	103.1
4	103.1	101.7	96.3	95.9	91.0[d]	101.1	103.4
5	102.2	101.9	98.3	98.1	97.5	99.5	dead
6	101.7	99.7	dead	……	……	……	……
7	103.4	100.9	96.9	99.5	dead	……	……
8	101.5	99.5	99.9	dead	……	……	……
9	101.9[b]	101.3	dead	……	……	……	……
10	102.6	101.3	97.5	dead	……	……	……
11	103.2	101.3	97.7	99.5	99.1	101.6	103.2
12	102.4	102.5	100.3	99.1	99.7	102.5	104.1
Total,	1226.7	1216.8	788.4	591.8	486.0	505.4	413.8
Average,	102.22	101.4	98.55	98.633[c]	97.2	101.8	103.45

Complete anæsthesia produced in 13 minutes. Mortality $66\frac{2}{3}$ per cent.

[a] Highest normal temperature.

[b] Suffering from epistaxis.

[c] Lowest average temperature.

[d] Lowest temperature.

TABLE IV.—SECOND EXPERIMENT WITH CHLOROFORM.

Rabbit. No.	Normal temp.	Temperature during anæsthesia.				Temp. 24 h'rs after.	Temp. 48 h'rs after.	Temp. 72 h'rs after.
		Temp. at 3.26 P. M.	Temp. at 3.51 P. M.	Temp at 4.24 P. M.	Temp. at 5.06 P. M.			
1	103.5[a]	101.5	101.2	100.7	dead	……	……	……
2	102.8	102.3	dead	……	……	……	……	……
3	103.6	102.0	97.6	94.5	92.1	102.1	102.2	104.0
4	102.1	100.9	99.5	dead	……	……	……	……
5	101.3[b]	101.1	97.7	93.5	90.0[c]	99.1	99.2	101.0
6	101.6	101.0	dead	……	……	……	……	……
7	102.7	100.9	100.8	97.3	95.5	101.9	103.6	102.5
8	102.5	100.1	98.1	94.9	93.5	101.9	102.1	102.3
9	102.6	102.1	101.1	99.1	dead	……	……	……
10	102.5	101.9	101.0	dead	……	……	……	……
11	102.3	100.7	99.2	97.5	97.1	99.1	100.2	103.0
12	103.1	102.7	100.1	99.1	dead	……	……	……
Total,	1227.9	1217.2	996.3	776.6	470.2	504.1	507.3	512.8
Average.	102.32	101.433	99.63	97.075	94.04[d]	100.82	101.46	102.56

Complete anæsthesia produced in 7 minutes. Mortality $58\frac{1}{3}$ per cent.

[a] Highest normal temperature.
[b] Lowest normal temperature.
[c] Temperature below 90.
[d] Lowest average temperature.

TABLE V.—EXPERIMENT WITH SULPHURIC ETHER.

Rabbit. No.	Normal temp.	Temperature during anæsthesia.			Temp. 24 hours after.	Temp. 48 hours after.
		Temp. at 3.13 P. M.	Temp. at 4.19 P. M.	Temp. at 5.13 P. M.		
1	101.8	100.0	97.8	96.2	102.3	102.2
2	101.8	101.9	97.7	97.7	102.8	102.1
3	101.8	101.1	99.8	100.1	102.9	102.3
4	102.8	100.7	96.8	92.2[b]	102.8	103.3
5	101.6	100.9	98.9	98.5	102.3	102.0
6	103.3	102.6	94.2	98.7[c]	104.6	103.8
7	102.6	100.0	97.4	94.8	103.2	103.0
8	103.3	102.1	100.1	97.8	103.6	103.8
9	103.2	102.3	dead	……	……	……
10	103.9[a]	102.6	98.2	97.7	102.5	104.4
11	103.3	102.3	94.2	99.3	102.8	103.8
12	101.8	97.7	dead	……	……	……
Total,	1231.2	1216.2	975.1	973.0	1030.7	1030.7
Average,	102.6	101.35	97.51	97.3[d]	103.07	103.07

Complete anæsthesia produced in 6 minutes. Mortality $16\frac{2}{3}$ per cent.

[a] Highest normal temperature.
[b] Lowest temperature.
[c] Temp. higher than when last taken.
[d] Lowest average temperature.

TABLE VI.—EXPERIMENT WITH ALCOHOL, CHLOROFORM, AND ETHER MIXTURE.[a]

Rabbit. No.	Normal temp.	Temperature during anæsthesia.				Temp. 24 h'rs after.	Temp. 48 h'rs after.
		Temp. at 3.15 P. M.	Temp. at 3 45 P. M.	Temp. at 4.15 P. M.	Temp at 5.15 P M.		
1	100.9	99.8	96.7	94.9	93.5	101.5	100.5
2	100.7	100.3	99.1	99.1	97.7	95.7	dead
3	101.9	98.7	97.0	95.7	dead	......	......
4	102.5	100.1	95.9	94.8	93.0	102.6	101.7
5	102.3	100.4	dead	......	......	......	......
6	102.4	100.1	96.6	94.0	92.0[c]	101.2	101.5
7	101.7	100.7	98.3	96.9	dead	......	......
8	102.4	101.3	98.7	96.2	dead	......	......
9	101.6	99.0	dead	......	......	......	......
10	102.4	100.7	dead	......	......	......	......
11	102.1	102.0	dead	......	......	......	......
12	102.7[b]	100.5	dead	......	......	......	......
Total,	1223.6	1203.6	682.3	671.6	376.2	401.0	303.7
Average,	101.96	100.3	97.47	95.94	94.05[d]	100.25	101.23

Complete anæsthesia produced in 20 minutes. Mortality 75 per cent. Three rabbits died just as mixture in flask was being exhausted.

[a] Alcohol 1 part, chloroform 2 parts, ether 3 parts.

[b] Highest normal temperature.

[c] Lowest temperature.

[d] Lowest average temperature.

TABLE VII.—EXPERIMENT WITH BROMIDE OF ETHYL, CHLOROFORM, AND ALCOHOL MIXTURES.[a]

Rabbit. No.	Normal temp.	Temperature during anæsthesia.			Temp. 24 hours after.	Temp. 48 hours after.
		Temp. at 3.30 P. M.	Temp. at 4 06 P. M.	Temp. at 5.30 P. M.		
1	103.9[b]	100.7	dead	......	......	......
2	101.0	101.6	96.9	97.0	102.8	102.6
3	102 8	100.0	96.8	95.0[c]	101.4	101.9
4	103.1	100.8	97.5	99.7	dead	.....
5	103.0	102.1	98.0	dead	......	......
6	103.5	102.1	99.6	dead	......	......
7	103.2	102.6	dead	......	......	......
8	101.8	101.7	95.2	dead	......	......
9	102.2	101.9	99.8	dead	......	......
10	102.8	99.7	98.7	97.2	101.0	102.7
11	103.7	100.7	97.2	98.5	101.8	101.8
12	102.6	103.6	dead	......	......	......
Total,	1235.6	1217.5	879.7	487.4	407.9	409.0
Average,	102.96	101.45	97.74	97.48[d]	101.97	102.25

Complete anæsthesia produced in 12 minutes. Mortality 66⅔ per cent.

[a] Bromide of ethyl 1 part, chloroform 3 parts, alcohol 4 parts.

[b] Highest normal temperature.

[c] Lowest temperature.

[d] Lowest average temperature.

Table VIII.—Experiment with Bromide of Ethyl, Chloroform, and Alcohol (1, 3, 4).

Dog. No.	Normal.			Half hour continuous influence.			One hour continuous influence.			One and half hour's continuous influence.			Two hours' continuous influence.		
	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp	Temp.	Pulse.	Resp.	Temp.
1	124	30	102.1	156	80	98.9	144	32	95.8	100	40	94.8	120	60	92.4[a]
2	80	44	100.5	108	30	103.0	104	24	102.5	96	36	102.6	86	44	102.1
3	130	44	103.0	130	70	102.0	140	36	100.0	102	40	99.4	102	36	98.5
4	100	26	103.4	110	23	103.7	108	29	100.1	130	30	98.5	131	39	97.2
5[b]	120	40	101.9	112	32	103.4	140	20	102.9	108	48	102.4	120	60	101.7
Total,	554	196	510.9	616	241	511.	636	141	501.3	536	194	497.7	559	239	491.9
Average,	110.8	39.2	102.18	123.2	48.2	102.2	127.2	28.2	100.2	107.2	38.8	99.54	111.8	47.8	98.38[c]

Mortality 80 per cent.

[a] Lowest temperature.

[b] Only dog that survived over 48 hours, and he was supposed to have died at a later date. He was the finest in all respects of the 25 used, and weighed about 60 pounds.

[c] Lowest average temperature.

Table IX.—Experiment with Bromide of Ethyl.

Dog. No.	Normal.			Half hour continuous influence.			One hour continuous influence.			One and half hour's continuous influence.			Two hours' continuous influence.		
	Pulse	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.
1	140	20	100.3	120	44	97.7	120	36	96.2	118	36	93.8	104	28	92.8[b]
2	80	48	101.9	82	46	100.9	...	...	......	...	...	......	...	...	......
3	140	32	102.1	178	40	103.2	170	80	101.7	168	80	100.1	150	48	97.4[c]
4	100	20	101.9	200	32	103.6	138	48	104.2	126	48	104.2	188	44	101.7[c]
5	60[a]	16	104.4	...	...	......	...	...	......	...	...	......	...	...	......
Total,	520	136	508.6	580	162	405.4	428	164	302.1	402	164	297.1	442	120	293.9
Average.	104	27.2	101.72	145	40.5	101.45	142.66	54.5	100.7	134	54.66	99.33	147.33	40	97.96[d]

Mortality 100 per cent.

[a] A pulse irregular and intermittent.

[b] Lowest temperature.

[c] Died within 24 hours after the operation.

[d] Lowest average temperature.

TABLE X.—EXPERIMENT WITH ETHER.

Dog. No.	Normal.			Half hour continuous influence.			One hour continuous influence.			One and half hour's continuous influence.			Two hours' continuous influence.		
	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.
1	132	20	100.3	140	60	94.0	126	56	90.8	160	56	91.0	154	72	.....[a]
2	120	20	103.0	170	20	103.1	152	19	103.0	160	20	97.1	152	20	96.6
3	124	26	101.9	150	32	98.7	180	56	94.2	170	40	92.4	160	40	90.4
4	100	40	104.8	166	50	101.9	140	62	98.5	154	54	96.2	140	64	93.2
5	158	26	101.6	150	42	100.8	156	34	97.8	80	32	96.2	70	40	95.2
Total,	634	132	511.6	776	204	498.5	754	227	484.3	724	202	472.9	676	236	465.4
Average,	126.8	26.4	102.32	155.2	40.8	99.7	150.8	45.4	96.86	144.8	40.4	94.58	135.2	47.2	93.08[b]

Mortality 0.

[a] Temperature below 90.

[b] Lowest average temperature.

TABLE XI.—EXPERIMENT WITH CHLOROFORM.

Dog. No	Normal.			Half hour continuous influence.			One hour continuous influence.			One and half hour's continuous influence.			Two hours' continuous influence.		
	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse	Resp.	Temp.	Pulse.	Resp.	Temp.
1	120	28	101.7	114	56	102.5	110	64	101.7	88	50	101.3	88	48	100.1
2	126	20	102.6	134	43	99.7	118	52	96.4	130	44	94.2	130	46	92.4[a]
3	120	36	103.9	126	58	101.9	130	58	97.9	120	62	96.8	100	56	96.0
4	120	38	101.9	130	48	101.7	152	48	100.3	128	42	98.7	160	40	97.7
5	130	22	102.3	120	41	101.7	118	36	100.5	114	28	98.3	120	52	97.4
Total,	616	144	512.4	624	245	507.5	628	258	496.8	580	228	489.3	598	242	483.6
Average,	123.2	28.8	102.48	104.8	49	101.5	125.6	51.6	99.36	116	45.2	97.46	110.0	48.4	96.72[b]

Mortality 0.

[a] Lowest temperature.

[b] Lowest average temperature.

TABLE XII.—EXPERIMENT WITH ALCOHOL, CHLOROFORM, AND ETHER (1, 2, 3).

Dog. No.	Normal.			Half hour continuous influence.			One hour continuous influence.			One and half hour's continuous influence.			Two hours' continuous influence.		
	Pulse	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.	Pulse.	Resp.	Temp.
1	80	28	101.5	...	...	......	...	...	......	...	...	......	...	...	......
2	104	44	102.1	100	48	98.5	120	32	97.7	132	44	95.6	160	24	93.6[a]
3	156	36	101.5	...	...	......	...	...	......	...	...	......	...	...	......
4	86	22	102.8	124	76	100.8	124	56	95.8	...	...	......	...	...	......
5	74	16	102.1	140	18	101.2	126	54	98.8	130	44	96.4	130	40	95.0
Total,	500	146	510.0	364	142	300.5	570	142	292.3	262	88	192	290	64	188.6
Average,	100	29.2	102.0	121.33	47.3	100.16	190	47.33	97.43	131	44	96	145	32	94.3[b]

Mortality 60 per cent.

Dog No. 3 died 30 minutes after commencing administration; just prior to death, which was caused by cardiac paralysis, the respirations were 54. The normal respirations were counted by Drs. B. A. W. and P. H. *Post-mortem* revealed pulmonary congestion; also congestion of meninges and brain, especially the former.

[a] Lowest temperature.

[b] Lowest average temperature.

The most casual inspection of the preceding tables cannot fail to impress the observer with the *relatively small mortality produced by the sulphuric ether*, when it is compared with that which followed the use of the bromide of ethyl, chloroform, or the mixtures which were employed. In our experiments on rabbits, we employed 82 animals, and 45 of these died from the effects of the anæsthetics. These animals were carefully watched while in the experimental cage during the administration of the anæsthetics, and, consequently, we know that more than three-fourths of the whole number of deaths occurred after their removal to the open air, while some of them continued to breathe under these circumstances one-half hour or even more.

The percentage of the mortality, produced by the different anæsthetics employed in our experiments on rabbits, was as follows :—[1]

Sulphuric Ether	.16$\frac{2}{3}$
Chloroform	.62$\frac{1}{2}$
Bromide of Ethyl	.50
Alcohol, Chloroform, and Ether mixture	.75
Alcohol, Chloroform, and Ethyl mixture	.66$\frac{2}{3}$

The whole number of dogs experimented on was 25, and among these, twelve deaths occurred, while the percentage of mortality chargeable to the different anæsthetics was as follows :—

Sulphuric Ether (none died)	.00
Chloroform " "	.00
Bromide of Ethyl (all died)	100.00
Alcohol, Chloroform, and Ether mixture . . .	.60
Alcohol, Chloroform, and Ethyl mixture . . .	.80

In connection with this *résumé* of the results obtained in our experiments on dogs, it seems proper to remark, that these animals received, during the time they were under the influence of these anæsthetic agents, the same attention, and that the drug was administered with the same care, as should be given in the case of human subjects, with the single exception that the administration was not permanently discontinued the moment the first unfavorable symptoms were observed. Further more, it should be observed as a point of considerable practical importance, that the bromide of ethyl, whether given in its purity or in combination with other anæsthetic agents, frequently causes more deaths within the forty-eight hours which immediately succeed its administration than during the period in which complete anæsthesia is maintained, especially when the latter has been long protracted; although sulphuric ether, chloroform, and their mixtures are generally entirely free from this danger.

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[1] Squibb's chloroform and ether were employed in all our experiments. Merck's bromide of ethyl was commonly employed by us, although we used a small quantity of this drug prepared by Rosengarten & Sons, of Philadelphia.

In none of our experiments on either rabbits or dogs did any deaths occur, subsequently to the discontinuance of the anæsthetic, which could be fairly attributed to the anæsthesia, in which the animal so far recovered as to be able to stand on its feet, except in those cases where we employed the bromide of ethyl or its mixtures. The bromide of ethyl was administered to five dogs; two died during the first hour; three were kept fully anæsthetized for two hours, but died within forty-eight hours after the discontinuance of the inhalation. The bromide of ethyl mixture was given to the same number of dogs, and all of them survived the two hours' complete anæsthesia; but some of them died within eight hours from its effects. Artificial respiration became necessary in consequence of a cessation of respiration fifteen times during the performance of our experiments on dogs, and the following represents the frequency with which it occurred in connection with each of the anæsthetics employed:—

Bromide of Ethyl	5 times.
Chloroform	2 "
Alcohol, Chloroform, and Ether	3 "
Alcohol, Chloroform, and Bromide of Ethyl	5 "
Sulphuric Ether	0 "

It was also observed that all dogs experimented on with bromide of ethyl, or its mixture, suffered from epistaxis during its administration, and this was followed by the flow of bloody serum from the nostrils, which generally continued until death occurred. The *post-mortem* examinations in these cases uniformly revealed congestion of the brain, lungs, liver, and kidneys, which was frequently very marked, while in the cases of death from chloroform the congestion was limited to the brain and lungs, and not so well defined. The blood in both cases was of a dark-red color. It will be seen in the record of our experiments on rabbits, by a reference to the tables exhibiting the variations of temperature caused by the inhalation of chloroform and ether, that the former is a much more depressing agent than the latter. The depressing effect of chloroform as an anæsthetic is shown by the fact that it required two or three days for the rabbits, which had been anæsthetized with this drug, to regain their normal temperature; while those to which the sulphuric ether had been administered the same length of time regained their natural warmth within two or three hours.

The tables show a very wide variation in the pulsations and respirations, especially as regards their frequency, and, it is important to remark in this connection, that we observed in all our experiments, *that death was invariably preceded by very rapid respirations, regardless of the anæsthetic which induced it.* The profession is indebted to Dr. H. C. Wood, of Philadelphia, for endeavoring to determine, by experiments on dogs, the physiological action of bromide of ethyl with especial reference to its use as an anæsthetic. He introduces his subject thus:—[1]

"The important physiological difference between chloroform and ether is in their action upon the heart, and my experiments have been chiefly directed to determining whether the bromide, like chloroform, is depressant to the arterial pressure, and, therefore, probably dangerous as an anæsthetic, or whether it shares the stimulant powers and the safety of ether."

We will now give his conclusions, which, we believe, are fully warranted by the results of his experiments, without entering into the details of the figures. He says:[2] "Extended analysis of these experiments is scarcely necessary. They certainly show that the bromide of ethyl may cause anæsthesia without reducing the blood-pressure, but also indicate that it is distinctly depressant to the circulation, reducing, when in excess, the force of the blood-current to a very marked extent. The suddenness of the drop in the arterial pressure seen in the latter part of Exp. II.[1] is unpleasantly suggestive of what has been witnessed so frequently in the surgical amphitheatre during the administration of chloroform. In Exp. III.,[1] a still more sudden loss of heart power occurred, the arterial pressure going down over forty per cent. in a single minute. In the human being, such a change of the pulse force would be most alarming. A marked contrast is seen in Exp. III.,[1] between the cardiac action of the bromide and of ether. By the bromide, the arterial pressure was reduced from '75–95' to '30–35.' The animal was then allowed to recover, and the anæsthesia was subsequently produced by ether, and pushed to the final limit, the arterial pressure was '70–80' at the time breathing practically ceased, and rose to '80–90' under the influence of the asphyxia, caused by the suspension of the respiration. In Exp. IV.,[1] a comparison was made between the bromide and chloroform. When the dog was fully anæsthetized with the first agent, and the effect of the early struggles had passed off, the pressure was from '50–90;' with chloroform, '65–95,' or, a little later, '50–65.' The bromide would seem, therefore, to rival the older anæsthetic in its depressant influence upon the circulation. That this action is exerted upon man as well as upon the lower animals is apparently shown by the sphygmographic studies which have been made at the University Hospital by Dr. Sheppard, Resident Surgeon.

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[1] Phila. Med. Times, vol. x. p. 371.

[2] Ibid., p. 372.

"The next step in this study of the bromide of ethyl was to determine whether the fall of arterial pressure is due to a direct action upon the heart. It was found that when the cut-out heart of a frog is touched with a drop of the bromide, or even when it is hung in the concentrated vapor, all movements cease at once. This, of course, indicates that the drug acts directly upon the heart-muscle or its contained ganglia. In order to be sure in the matter, three experiments were performed; one of these has already been noted, the other two are expressed graphically upon the succeeding page. Tracing No. 1[1] was obtained for comparison by injecting a fluidrachm of *ether* into the jugular vein, so that the whole of it should be precipitated at once upon the heart. Tracing No. 2[1] portrays the result of a similar injection of a similar amount of the *bromide.* In both these cases the animal was in a normal state; but in the experiment represented by tracing No. 3,[1] the pneumogastrics were divided previous to the injection of a half drachm of the bromide of ethyl.

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[1] Wood's experiments.

"The tracings do not need any discussion; taken along with the trials made upon the frog's heart, they prove that the bromide of ethyl acts as a cardiac paralyzant. The influence of the anæsthetic resembles, therefore, that of chloroform, and not that of ether; and it is altogether probable that it shares the dangerous properties of chloroform."

The study of the effects of the bromide of ethyl in our experiments has so far harmonized our views with those expressed by Dr. H. C. Wood, that we are now prepared to assert that the primary effect of this anæsthetic *does resemble that of chloroform, and not that of ether;* but it is certainly much more dangerous than the former agent, especially when full anæsthesia is continued with it for the period of two hours. The deaths which occurred in our experiments during the administration of the ethyl are believed to have been caused by its paralyzing action on the heart, while those occurring at a later period were probably more or less dependent on the same; but in these cases the *post-mortem* appearances reveal extreme congestion of the principal visceral organs, with other indications of inflammation, in all cases where death was sufficiently delayed.

We have now reached a point in our study of the various anæsthetics where we believe we are justified in *firmly asserting,* in the light of the theoretical and practical knowledge which we now possess of the action of the bromide of ethyl, that neither this drug nor its mixture should ever be employed for the production of anæsthesia, especially where it is necessary to prolong this state. It has long since been sufficiently shown that sulphuric ether is decidedly the safest anæsthetic which has yet been employed in general surgical practice; and our experiments are merely confirmatory of the correctness of this decision. The use of a mixture of alcohol, chloroform, and ether, for the purpose of producing anæsthesia, is theoretically wrong and practically bad, since it is unquestionably much more dangerous than sulphuric ether.

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[1] Wood's experiments.

DISCUSSION.

Dr. W. W. Dawson, of Cincinnati, Ohio.

I have been very much interested in Dr. Watson's contribution. As you, Mr. President, last year remarked in connection with Dr. Senn's paper—this experimental work is of the utmost value.

I have had a somewhat painful experience with anæsthetics. I have lost two patients while under the influence of chloroform, one a woman in 1869, another a boy in 1874. I was amputating (making Syme's operation) Bridget Henry's foot in the amphitheatre of the Cincinnati Hospital, when suddenly I said to myself, "How well the tourniquet is acting." In an instant the alarm was sounded—she was dead. We kept up artificial respiration for one hour and three-quarters, but we could not start the heart. An examination showed her to be a healthy woman; nothing except a few insignificant pleuritic adhesions could be found. I was operating for malignant tumor upon the foot. At that time we were hardly willing to admit that chloroform could kill; deaths were attributed to shock, hemorrhage, etc. In preparing a paper, I collected (in six weeks) eleven other unpublished deaths from chloroform, which had occurred in Cincinnati and its neighborhood and within the observation of medical gentlemen residing there. In that paper I assumed what has been proved to be a very erroneous opinion, that chloroform was no more dangerous than ether, and that the only reason that the latter did not rival the former in mortality was the fact that the one was given so infrequently. I continued the use of chloroform until 1874, when I lost a German boy upon whom I was making an osteotomy of the lower jaw. The tumor was small, the blood flowed freely, when suddenly the field of the operation became bloodless. We were startled, but in an instant the blood flowed, and my colleague, Dr. Conner, who was assisting me, assured me that he was all right. The operation was resumed, and again the blood stopped, but instantly flowed; the field becoming bloodless the third time closed the scene. The heart was fatally paralyzed.

The celebrated case of Nélaton was fresh before the profession at that time, and we resorted to the plan for resuscitation so graphically given by the late Marion Sims; suspending him we dashed the blood upon his brain in accordance with the theory of that distinguished surgeon, that chloroform death depended upon cerebral anæmia. We tested this plan thoroughly; but by dashing fresh blood upon the brain we could not stimulate the pneumogastric.

In both of my cases death was characterized by the same condition of the field of operation—bloodlessness—showing conclusively death by the heart.

About this time the experiments of Smythe and Simon were published, proving by experiments upon animals that chloroform kills by paralyzing the heart, whilst ether destroys by embarrassing the lungs. Both of my cases were now clearly revealed—paralysis of the centre of circulation, hence cerebral anæmia. Could I have realized this after my first I might have saved my second case. I was thus reluctantly compelled to abandon chloroform, for when the heart is smitten it is likely to be fatal. Embarrassment of respiration is not likely to give serious trouble.

There is one other point which I would like to present. The amount of chloroform administered, and the length of time under which the patient is kept, are not, I think, essential factors of danger. If a patient tolerates it at all, he may use it, I was going to say indefinitely. I knew an eminent surgeon who was under its influence for six weeks previous to his death from hepatic dropsy. One of the cases reported by me, Mrs. G., went into a dental office to have a tooth extracted; she told the dentist that he need not send for a physician, that she had taken chloroform a hundred times; he, however, sent for one, but before she had taken a half dozen inspirations she was dead; her heart was fatally smitten. Dr. Stewart, of Ohio, who reported this case to me, assured me that Mrs. G. had taken chloroform in eight confinements, that in one of them he had kept her under its continuous influence for twelve consecutive hours. The lesson here is striking; it is, as I have intimated, that the danger from chloroform does not depend upon the amount given or the length of time of its administration, but upon the condition of the patient that day, that hour, it may be that moment. In neither of my cases were there used two drachms of chloroform.

The PRESIDENT. Dr. Dawson, did you say that the lady who died in the dentist's chair was in the sitting position?

Dr. DAWSON. Yes, sir; the heart is in more danger when the patient is in the sitting than in the recumbent position.

The PRESIDENT. That was a very striking case; it is well for us to consider it. Here is a woman who had taken chloroform a great deal. But she took it in the semi-recumbent position for the first time in her life, and she died.

Dr. DONALD MACLEAN, of Detroit, Michigan.

I have recently had a peculiar experience which it seems to me proper to bring before the Association in this connection. Just about a week ago, I was asked to see, with a brother physician of Detroit, a case of supposed ovarian tumor. I went with him and examined the case in a somewhat cursory manner, because it was a very plain and easy one to diagnosticate. The patient was of a robust, healthy stock, about 44 years of age, and Scotch by birth. I had quite a little talk with her before the examination, about Scotland and mutual friends there, then made the examination with the understanding that the doctor and I were to arrange for the operation. During our conversation, however, I had noticed that the patient seemed to be somewhat embarrassed in her breathing; she seemed to have a slight asthmatic cough, and a little lividness of countenance, a condition not at all infrequent in Michigan, on account of the prevalence of hay asthma and catarrh in that section, so that I did not attach much importance to it. As we were leaving the house, my friend said to me: "That is a nice case, and I should like to make the operation myself." Shortly after, Dr. Richards came to my office and said: "I have changed my opinion; I will let you do that operation. I believe it is a bad case, because the pedicle seems so short." I told him that that did not make much difference, and the only thing I did not like was that the woman's breathing was not good. He then said: "Well, the fact is that before we had driven from the house two blocks the woman was dead." This case goes to prove that the patient may die, not only from the first whiff of chloroform, but that she may die *before* she has had the first whiff.

Dr. Simpson used to tell this story: "When it was first of all proposed to try chloroform in an important surgical operation, he and Liston had made an appointment to perform one under chloroform. Owing to Simpson's being a little late, Liston decided to begin without the use of an anæsthetic. The patient was hardly touched with the point of the knife when he died." Had chloroform been used in this case, I believe the practice of anæsthesia in surgery would have received a blow which it would not have recovered from in one generation.

I have this to say: For twenty-five years I have been giving chloroform liberally indeed, and I have yet to see an accident. I can count on the fingers of my one hand all the cases in which I have been alarmed in the use of chloroform. One of these occurred a few months ago, in an amputation of the entire tongue for cancer. I operated with the écraseur. Owing to the instrument not working perfectly, there was some hemorrhage just at the close of the operation. The first inspiration, of course, drew blood into the glottis, and caused a stoppage of respiration. We soon succeeded, however, in getting the blood out of the larynx, and, after keeping up artificial respiration for a short time, the patient revived. The situation, however, was undoubtedly most critical for some minutes.

I believe that Dr. Dawson's experience, stated so clearly and distinctly and forcibly, furnishes the key to this subject. I believe that in his second case, at the moment the field of operation became bloodless, if his assistant, who was giving the chloroform, had been sharp, the danger might have been avoided. It was too late when the field became bloodless a second time. The condition of the patient should have given warning before that stage was reached, and the proper means applied.

I believe in using chloroform, but I believe just as strongly in having an experienced assistant, who is trained and competent to meet any emergency that may arise. I am willing to stick to my statement, although I make it in no dogmatic spirit. I believe that chloroform properly administered is a safe anæsthetic agent.

Dr. William A. Byrd, of Quincy, Illinois.

I have lost one patient from the effects of chloroform; a woman who had several times been operated upon for a vesico-vaginal fistula. The first time I saw her, she was kept under ether for nine hours by the surgeon in whose charge she then was. When I made my operation, I kept her a little more than an hour under chloroform. I had gotten all the parts ready for removing the sutures. She refused, however, to let me remove them without an anæsthetic. She only breathed a few times after the chloroform was administered, when she died. We maintained artificial respiration for awhile, but without avail. When the bromide of ethyl was introduced, I seized upon it at once, and thought that it would do well. On one occasion I was alarmed by the condition of a patient suddenly becoming flushed and red to an alarming degree. Then hearing of some disastrous results of its use in Nashville, I became afraid of it. I then tried mixing it with chloroform and alcohol, in the proportions of one ounce of bromide of ethyl to two ounces of chloroform and three ounces of alcohol. But I did not altogether like this, for once when my assistant was not paying close attention a patient was nearly asphyxiated. Since then, however, I have used it in a large number of cases, and have not had a bad result. It is also a very economical mixture, for in all of these cases I have used just four pounds. I use Dr. Johnson's inhaler, and that makes a great difference. It renders the inhalation perfectly safe. The rubber mouth-piece fits perfectly over the face; there is a place to put a sponge to hold the anæsthetic, and a wire gauze to keep it from falling through. By leaving out the stopper for awhile, a draft of air passes through it. I leave out the cork during the first part of the inhalation, until the patient gets used to it. A death may occur from this mixture sometimes, but as long as I have an assistant who is competent I think it is perfectly safe.

The President. All three gentlemen have spoken of using artificial respiration, but the methods of artificial respiration have not been mentioned. You used Sylvester's method, did you not?

Dr. Byrd. Yes, sir.

Dr. L. McLane Tiffany, of Baltimore, Maryland.

The remarks of the later speakers have been confined to ether and chloroform. In the paper that was read, we are given some experiments on the use of bromide of ethyl. I have not been so fortunate as to see experiments with the bromide of ethyl on animals, but I have seen it used in quite a large number of instances on the human subject. I understood the author of the paper to say that its action is similar to that of chloroform. Clinically, I must negative that absolutely. One of the late speakers has given us one of the most prominent symptoms. During inhalation of the bromide of ethyl, the face is extremely red. We are, of course, familiar with the commencement of its use, originating, as it did, in Philadelphia, and we are familiar with the classic case of Dr. Sims, in which for a long period of time it was used, and the patient died. We are all familiar with Dr. Squibb, of Brooklyn; and the outcome of his investigations was the belief that the materials inhaled were changed in their chemical structure, and became poisonous after a certain time in the body. It therefore fell, I think, into unmerited disregard. In a paper published a few years ago by Dr. Chisholm, of Baltimore, he reports over three hundred cases of its use without any trouble. None of the operations required much time. They were extractions of cataracts, iridectomies, slitting the punctum, etc.; all operations which could be done, and were done, in a short time, and the results of the operations were excellent. As regards the ease with which the anæsthetic was administered, as regards the ease with which the operator did what he had to do, and the ease and facility with which the patients recovered, it was unequalled. I would preface what I have to say, too, with the remark that a safe anæsthetic is not known; that it is not possible to obtain insensibility—to carry a patient to the border line of life, without some one getting a little beyond that line, and never coming back. It is, therefore, a question as to the agent which is least liable to produce death. In the opinion of Dr. Chisholm, to whom I have referred, the bromide of ethyl is the most serviceable for short operations. After reading his paper, I saw it given in his operations frequently, and I have since used it myself.

Of course, as with every other anæsthetic, certain precautions should be taken. The patient ought to have an empty stomach. Everything should be loose about the neck and waist. The patient is to be in a recumbent position, and then he should be instructed how to breathe. He should go through the operation of inspiring and expiring rapidly before the inhalation is commenced. Then the patient takes the anæsthetic. In a few moments the face becomes extremely red, the anæsthesia becomes complete; the operation is made, and the patient recovers almost immediately. The operation should never take more than a minute. The anæsthesia passes off in a very short time, and if induced again, the patient almost certainly has some bad result. A third administration I have not seen. A second administration, because the operation ran over the time required, I have never seen, but I am quoting from papers I have read. After the operation is done, the patient will rise, and the mind will take up the same train of thought as was present when he went under the anæsthetic. In the paper quoted, and I have since seen almost the same thing, the patient was a little girl who was operated upon for strabismus. Just before the operation she laid a dress she had been playing with on a chair. Immediately after the operation, she ran to the chair, picked up the dress and ran out. I do not think the bromide of ethyl and chloroform can be compared in the human subject. For short operations, so far as I can say clinically, the bromide is an extremely good agent. Of course, we must always keep in view the fact that the patient will sometimes get beyond the boundary line.

Dr. P. S. CONNER, of Cincinnati, Ohio.

I would like to ask the last gentleman what action the bromide of ethyl has on the heart?

Dr. TIFFANY. It was reported to me as not markedly varying after the first moment. I have not noticed it myself.

Dr. CONNER. When the agent was introduced, I took occasion to use it somewhat extensively in the wards of the Cincinnati Hospital. I was astonished and not a little surprised at its action on the pulse. I have seen a pulse go up from 80 to 180, the respirations at the same time reaching 70 and more in the minute. I have never seen an agent so kind in its action, and at the same time so profound. I have amputated an arm in sixty seconds after beginning the anæsthetic, and I have had patients to get off the table, walk to the elevator, and go out in two minutes after concluding the operation. If it were as safe, I should prefer it above all others. But I do not see how an agent with such profound action can be safe.

I saw the case reported by Dr. Dawson. Thirty days after, I saw a woman with a dislocation of the shoulder. After profound anæsthesia had been produced with chloroform, I picked up the arm for the purpose of reducing the dislocation. Hardly had I picked it up and commenced a little manipulation when she died. Both in military and civil practice, I had used it over and over again, and had declared that the danger from chloroform was because it was given improperly. But it has been conclusively shown that chloroform acts directly upon the large vessels and the heart. A certain class of cases die from its effect on the lungs, but they are cases in which profound anæsthesia has been kept up for a long time. When the heart has once stopped, all attempts to revive the patient must, in the great majority of cases, be useless, and it is absurd, it seems to me, to talk of starting the circulation by turning the patient upside-down, or throwing him around, in the attempt to get the blood into the head. You might as well turn it into any other inelastic case.

I have given chloroform but twice since the case I have related. I think we are compelled to use ether because it is so much safer. The bromide of ethyl, it seems to me, would be the most acceptable anæsthetic, if it were not for its intense and uncertain action.

The PRESIDENT. I would suggest that the paper of Dr. Cheever be now read, before we go on any further with the discussion of Dr. Watson's paper. The subjects are so intimately related, that I think we could more profitably discuss them together.